

## CLAIMS

Having thus described the aforementioned invention, we claim:

- 1        1. A boiler in which a liquid medium is heated, said boiler
- 2        comprising:
  - 3            a housing having first and second ends;
  - 4            a lower drum for receiving the liquid medium, at least a portion of
  - 5            said lower drum being disposed within said housing;
  - 6            an upper drum at least a portion of which is disposed within an upper
  - 7            portion of said housing, said upper drum having an outlet;
  - 8            at least a first tube bank disposed within said housing on a first side
  - 9            of said upper drum, said first tube bank including a plurality of first fluid
  - 10          tubes for establishing fluid communication between said lower drum and
  - 11          said upper drum, each said first fluid tube defining at least one inwardly
  - 12          extending portion;
  - 13          at least a second tube bank disposed within said housing on a second
  - 14          side of said upper drum, said second tube bank being disposed
  - 15          substantially opposite said first tube bank, said second tube bank including
  - 16          a plurality of second fluid tubes for establishing fluid communication
  - 17          between said lower drum and said upper drum, each said second fluid tube
  - 18          defining at least one inwardly extending portion which is longer than said
  - 19          inwardly extending portions of said first fluid tubes of said first tube bank,
  - 20          whereby said first and second tube banks define a combustion area within
  - 21          said housing, and cooperatively define with said housing at least a first level
  - 22          of passageways for communicating hot gases;
  - 23          a burner for generating hot gases within said combustion area; and
  - 24          means for communicating hot gases from said combustion area to
  - 25          said first level of passageways and for communicating hot gases from said
  - 26          first level of passageways to said upper portion of said housing, whereby

27 heat from said hot gases is transferred to the liquid medium within said first  
28 and second fluid tubes thereby heating the liquid medium.

1       2. The boiler of claim 1 wherein said boiler further comprises at  
2 least one said first tube bank on said second side of said upper drum, and  
3 at least one said second tube bank on said first side of said upper drum,  
4 said first tube bank on said second side of said upper drum being disposed  
5 substantially opposite said second tube bank on said first side of said upper  
6 drum, whereby said first level of passageways defines at least three  
7 passageways providing linear paths for hot gases to travel.

1       3. The boiler of Claim 1 wherein said boiler comprises a plurality  
2 of said first and second tube banks alternately disposed on said first side of  
3 said upper drum, and a plurality of first and second tube banks alternately  
4 disposed on said second side of said upper drum, each said first tube bank  
5 being disposed opposite one said second tube bank, whereby said first level  
6 of passageways defines at least three passageways providing linear paths for  
7 hot gases to travel and whereby serpentine gas flow between said three  
8 passageways is permitted.

1       4. The boiler of Claim 1 wherein each said first fluid tube defines a  
2 second inwardly extending portion above said first inwardly extending  
3 portion of said first fluid tube, and wherein each said second fluid tube  
4 defines a second inwardly extending portion above said first inwardly  
5 extending portion of said second fluid tube, whereby said first and second  
6 tube banks define said first level of passageways, a second level  
7 passageway, and a third level of passageways.

1       5. The boiler of Claim 4 wherein said boiler comprises a plurality  
2 of said first and second tube banks alternately disposed on said first side of

3 said upper drum, and a plurality of first and second tube banks alternately  
4 disposed on said second side of said upper drum, each said first tube bank  
5 being disposed opposite one said second tube bank, whereby said first and  
6 third levels of passageways each define at least three passageways providing  
7 linear paths for hot gases to travel and whereby serpentine gas flow between  
8 said passageways of said first level of passageways is permitted and  
9 serpentine gas flow between said passageways of said third level of  
10 passageways is permitted.

1       6. A boiler in which a liquid medium is heated, said boiler  
2 comprising:

3           a housing having first and second ends, and an upper interior  
4 portion;

5           a lower drum for receiving the liquid medium, at least a portion of  
6 said lower drum being disposed within said housing;

7           an upper drum at least a portion of which is disposed within an upper  
8 portion of said housing, said upper drum having an outlet and first and  
9 second sides;

10          a plurality of first tube banks disposed within said housing on each  
11 said first and second side of said upper drum, each said first tube bank  
12 including a plurality of first fluid tubes for establishing fluid communication  
13 between said lower drum and said upper drum, each said first fluid tube  
14 defining at least a first inwardly extending portion;

15          a plurality of second tube banks disposed within said housing on  
16 each said first and second side of said upper drum, each said second tube  
17 bank being disposed substantially opposite one of said first tube banks;  
18 each said second tube bank including a plurality of second fluid tubes for  
19 establishing fluid communication between said lower drum and said upper  
20 drum, each said second fluid tube defining at least a first inwardly  
21 extending portion which is longer than said inwardly extending portions of

22 said first fluid tubes of said first tube banks, said first and second tube  
23 banks being alternately disposed along said first and second sides of said  
24 upper drum, whereby said first and second tube banks define a combustion  
25 area within said housing and cooperatively define with said housing at least  
26 a first level of passageways for communicating hot gases, said first level of  
27 passageways including first, second and third passageway, whereby linear  
28 flow of hot gases is permitted through said first, second and third  
29 passageways, and serpentine flow of hot gases is permitted between said  
30 first, second and third passageways;

31       a burner mounted at said first end of said housing for generating hot  
32 gases within said combustion area; and

33       means for communicating hot gases from said combustion area to  
34 said first level of passageways proximate said second end of said housing,  
35 and for communicating hot gases from said first level of passageways to said  
36 upper interior portion of said housing whereby heat from said hot gases is  
37 transferred to the liquid medium within said first and second fluid tubes  
38 thereby heating the liquid medium.

1           7.     The boiler of Claim 6 wherein each said first fluid tube defines a  
2 second inwardly extending portion, and each said second fluid tube defines  
3 a second inwardly extending portion, said second inwardly extending  
4 portion each of said second fluid tubes being longer than said second  
5 inwardly extending portions of said first fluid tubes, whereby said first and  
6 second tube banks define a second level passageway between said first and  
7 second inwardly extending portions of said first and second fluid tubes, and  
8 said first and second tube banks define a third level of passageways defining  
9 first, second and third passageways.

1           8.     The boiler of Claim 7 wherein said means for communicating  
2 hot gases from said combustion area to said first level of passageways

3 proximate said second end of said housing, and for communicating hot  
4 gases from said first level of passageways to said upper portion of said  
5 housing, further communicates hot gases from said first level of  
6 passageways to said second level passageway proximate said first end of  
7 said housing, communicates hot gases from said second level passageway  
8 to said third level of passageways proximate said second end of said  
9 housing, and communicates hot gases from said third level of said  
10 passageways to said upper interior portion of said housing proximate said  
11 first end of said housing.

1           9.     The boiler of Claim 8 wherein each said first fluid tube defines a  
2 lower leg portion which extends a selected distance from said lower drum  
3 outwardly toward an associated sidewall of said housing, and bends to  
4 define an upwardly extending portion communicating with said first  
5 inwardly extending portion of said first fluid tube, each said first and second  
6 inwardly extending portion of each said first fluid tube having a first tube  
7 run extending inwardly away from said associated sidewall of said housing  
8 and a reverse bend extending from said first tube run to a second tube run  
9 extending toward said associated sidewall of said housing, each said first  
10 fluid tube having a further reverse bend joining said first and second  
11 inwardly extending portions of said first fluid tube, and each said first fluid  
12 tube extending upwardly from said second inwardly extending portion and  
13 defining a further tube run terminating at said upper drum, and wherein  
14 each said second fluid tube defines a lower leg portion which extends a  
15 selected distance from said lower drum outwardly toward an associated  
16 sidewall of said housing, and bends to define an upwardly extending portion  
17 communicating with said first inwardly extending portion of said second  
18 fluid tube, each said first and second inwardly extending portion of each  
19 said second fluid tube having a first tube run extending inwardly away from  
20 said associated sidewall of said housing and a reverse bend extending from

21 said first tube run to a second tube run extending toward said associated  
22 sidewall of said housing, each said second fluid tube having a further  
23 reverse bend joining said first and second inwardly extending portions of  
24 said second fluid tube, and each said second fluid tube extending upwardly  
25 from said second inwardly extending portion and defining a further tube run  
26 terminating at said upper drum.

1       10. The boiler of Claim 8 wherein said means for communicating  
2 hot gases from said combustion area to said first level of passageways  
3 proximate said second end of said housing, and for communicating hot  
4 gases from said first level of passageways to said upper portion of said  
5 housing includes a plurality of oppositely disposed third fluid tubes  
6 proximate said second end of said housing communicating between said  
7 lower drum and said upper drum, and a plurality of oppositely disposed  
8 fourth fluid tubes proximate said first end portion of said housing  
9 communicating between said lower drum and said upper drum, said third  
10 fluid tubes being bent to permit hot gases to be communicated from said  
11 combustion area to said first level passageways, and from said second level  
12 passageway to said third level passageways, said fourth fluid tubes being  
13 bent to permit hot gases to be communicated from said first level  
14 passageways to said second level passageway, and from said third level  
15 passageways to said upper interior portion of said housing.

1       11. The boiler of Claim 9 wherein said means for communicating  
2 hot gases from said combustion area to said first level of passageways  
3 proximate said second end of said housing, and for communicating hot  
4 gases from said first level of passageways to said upper portion of said  
5 housing includes a plurality of oppositely disposed third fluid tubes  
6 proximate said second end of said housing communicating between said  
7 lower drum and said upper drum, and a plurality of oppositely disposed

8       fourth fluid tubes proximate said first end portion of said housing  
9       communicating between said lower drum and said upper drum, said third  
10      fluid tubes being bent to permit hot gases to be communicated from said  
11      combustion area to said first level passageways, and from said second level  
12      passageway to said third level passageways, said fourth fluid tubes being  
13      bent to permit hot gases to be communicated from said first level  
14      passageways to said second level passageway, and from said third level  
15      passageways to said upper interior portion of said housing.

1           12. The boiler of Claim 11 wherein each said third fluid tube defines  
2        a lower leg portion which extends a selected distance from said lower drum  
3        outwardly toward an associated sidewall of said housing and bends to  
4        define an upwardly extending portion, each said third tube defining at least  
5        one inwardly extending portion having an inwardly extending tube run, an  
6        upwardly extending tube run, and an outwardly extending tube run, said  
7        third fluid tube extending upwardly from said inwardly extending portion of  
8        said third fluid tube and defining a further tube run terminating at said  
9        upper drum.

1           13. The boiler of Claim 12 wherein each said fourth fluid tube  
2        defines a lower leg portion which extends a selected distance from said  
3        lower drum outwardly toward an associated sidewall of said housing and  
4        bends to define an upwardly extending portion, each said fourth fluid tube  
5        defining at least one inwardly extending portion having an inwardly  
6        extending tube run, an upwardly extending tube run, and an outwardly  
7        extending tube run, each said fourth fluid tube extending upwardly from  
8        said inwardly extending portion of said fourth fluid tube and defining a  
9        further tube run terminating at said upper drum.

1       14. A boiler in which a liquid medium is heated, said boiler comprising:  
2              a housing having first and second ends, and an upper interior  
3              portion;  
4              a lower drum for receiving the liquid medium, at least a portion of  
5              said lower drum being disposed within said housing;  
6              an upper drum at least a portion of which is disposed within an upper  
7              portion of said housing, said upper drum having an outlet and first and  
8              second sides;  
9              a plurality of first tube banks disposed within said housing on each  
10             said first and second side of said upper drum, each said first tube bank  
11             including a plurality of first fluid tubes for establishing fluid communication  
12             between said lower drum and said upper drum, each said first fluid tube  
13             defining a lower leg portion which extends a selected distance from said  
14             lower drum outwardly toward an associated sidewall of said housing and  
15             bends to define an upwardly extending portion communicating with a first  
16             inwardly extending portion of said first fluid tube, said first inwardly  
17             extending portion including a first tube run extending inwardly from said  
18             upwardly extending portion away from said associated sidewall of said  
19             housing and including a reverse bend extending from said first tube run to a  
20             second tube run extending toward said associated sidewall of said housing  
21             where said first fluid tube defines a further reverse bend, said first fluid  
22             tube further defining a second inwardly extending portion including a first  
23             tube run extending inwardly from said further reverse bend away from said  
24             associated sidewall of said housing and including a reverse bend extending  
25             from said first tube run to a second tube run extending toward said  
26             associated sidewall of said housing, said first fluid tube extending upwardly  
27             from said second inwardly extending portion and defining a further tube run  
28             terminating at said upper drum;  
29              a plurality of second tube banks disposed within said housing on  
30             each said first and second side of said upper drum, each said second tube

31 bank being disposed substantially opposite one of said first tube banks,  
32 each said second tube bank including a plurality of second fluid tubes for  
33 establishing fluid communication between said lower drum and said upper  
34 drum, each said second fluid tube defining a lower leg portion which  
35 extends a selected distance from said lower drum outwardly toward an  
36 associated sidewall of said housing and bending to define an upwardly  
37 extending portion communicating with a first inwardly extending portion of  
38 said second fluid tube, said first inwardly extending portion of said second  
39 fluid tube including a first tube run extending inwardly from said upwardly  
40 extending portion away from said associated sidewall of said housing and  
41 including a reverse bend extending from said first tube run to a second tube  
42 run extending toward said associated sidewall of said housing where said  
43 second fluid tube defines a further reverse bend, said second fluid tube  
44 further defining a second inwardly extending portion including a first tube  
45 run extending inwardly from said further reverse bend of said second fluid  
46 tube away from said associated sidewall of said housing, and including a  
47 reverse bend extending from said first tube run of said second inwardly  
48 extending portion of said second fluid tube to a second tube run extending  
49 toward said associated sidewall of said housing, said second fluid tube  
50 extending upwardly from said second inwardly extending portion and  
51 defining a further tube run terminating at said upper drum, said first and  
52 second inwardly extending portions of said second fluid tubes being longer  
53 than said first and second inwardly extending portions of said first fluid  
54 tubes, and said first and second tube banks being alternately disposed  
55 along said first and second sides of said upper drum, whereby said first and  
56 second tube banks define a combustion area within said housing,  
57 cooperatively define with said housing at least a first level of passageways  
58 for communicating hot gases, define a second level passageway for  
59 communicating hot gases, and cooperatively define with said housing a  
60 third level of passageways, said first level of passageways including a first,

61 second and third passageways and said third level of passageways including  
62 first, second and third passageway;

63 a burner mounted at said first end of said housing for generating hot  
64 gases within said combustion area; and

65 a plurality of oppositely disposed third fluid tubes proximate said  
66 second end of said housing communicating between said lower drum and  
67 said upper drum, and a plurality of oppositely disposed fourth fluid tubes  
68 proximate said first end portion of said housing communicating between  
69 said lower drum and said upper drum, said third fluid tubes being bent to  
70 permit hot gases to be communicated from said combustion area to said  
71 first level passageways, and from said second level passageway to said third  
72 level passageways, said fourth fluid tubes being bent to permit hot gases to  
73 be communicated from said first level passageways to said second level  
74 passageway, and from said third level passageways to said upper interior  
75 portion of said housing.

1 15. The boiler of Claim 14 wherein each said third fluid tube defines  
2 a lower leg portion which extends a selected distance from said lower drum  
3 outwardly toward an associated sidewall of said housing and bends to  
4 define an upwardly extending portion, each said third tube defining at least  
5 one inwardly extending portion having an inwardly extending tube run, an  
6 upwardly extending tube run, and an outwardly extending tube run, said  
7 third fluid tube extending upwardly from said inwardly extending portion of  
8 said third fluid tube and defining a further tube run terminating at said  
9 upper drum.

1 16. The boiler of Claim 15 wherein each said fourth fluid tube  
2 defines a lower leg portion which extends a selected distance from said  
3 lower drum outwardly toward an associated sidewall of said housing and  
4 bends to define an upwardly extending portion, each said fourth fluid tube

5 defining at least one inwardly extending portion having an inwardly  
6 extending tube run, an upwardly extending tube run, and an outwardly  
7 extending tube run, each said fourth fluid tube extending upwardly from  
8 said inwardly extending portion of said fourth fluid tube and defining a  
9 further tube run terminating at said upper drum.

1           17. The boiler of Claim 14 wherein said boiler includes a first  
2 downcomer disposed outside of said housing for establishing fluid  
3 communication between said upper drum and said lower drum.

1           18. The boiler of Claim 17 wherein said boiler includes a  
2 second downcomer disposed outside of said housing for establishing fluid  
3 communication between said upper drum and said lower drum.